

REMARKS

This application was originally filed with Claims 1-15. Claims 1-6, 8-11 and 13-15 are now pending in the application. As a result of an earlier request for reconsideration of Final Rejection, the finality was withdrawn and this response is to a non-final action.

In the Office Action, Claims 1-6, 8-11 and 13-15 are rejected. In addition, the specification is objected to by the Examiner.

SPECIFICATION

Item 4 of Office Action: The specification was objected to the basis that the specification contains "Au₃Al"; whereas 21.5 wt% Al binary Au actually constitutes "AuAl₂". This correction has been made.

CLAIM OBJECTIONS

Item 5 of Office Action: Claims 2 and 3 were objected to on the basis of "Au₃Al" similar to the objection to the specification. Claims 2 and 3 have been amended accordingly.

REJECTION UNDER 35 U.S.C. § 102/103

Item 8 of Office Action: Claims 1-4, 10 and 11 are rejected under 35 U.S.C. § 102(b) as being anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over the publication *Precious Metals* (edited by Benner et al., pub. by The International Precious Metals Institute, 1991, pages 443-447).

The basis of this rejection is that *Precious Metals* states “when aluminum content increases, the alloy becomes whitish with a violet color appearing when aluminum reaches 15%, the violet color becoming strong when the composition *approaches* AuAl₂” (emphasis added by Examiner).

However, this is a mere statement directed to a broad range of aluminum and refers to transition from a whitish color to a violet color, and then a stronger violet color. There is no basis in *Precious Metals* to discern a further narrower selection in the range corresponding to requisite important property of toughness. This property is identified as being important for the first time in the present invention, which defines that gold is present in an amount of 76-83.5 wt% (Claim 1). The significance of this narrow range, which is nowhere taught in *Precious Metals* or any of the art of record, is taught only by the present invention.

The composition in the present application namely, 76-83.5 wt% gold and 16.5-21.5 wt% aluminum, is not anticipated because it is well known that a genus does not always anticipate a claim to a species within the genus. Further with regard to ranges, if no specific examples in the prior art fall within the claimed range, a case-by-case determination must be made as to anticipation. See MPEP 2131.01 et. seq. See also *Corning Glassworks v. Sumitomo Electric USA, Inc.*, 868F.2d 1251, 1262, 9 U.S.P.Q.2d, 1962, 1970 (Fed. Cir. 1989), which stands for the proposition that a genus does not always anticipate a species within the genus, particularly in the case where the prior art genus did not identically disclose or describe, within the meaning of section 102, the claim species, since the genus would include an untold number of species. Thus, the effect of the disclosure of a genus on the patentability of a species

depends on the size of the genus and the disclosure of the preferred sub-genera and/or species, if any. More particularly, a genus will anticipate a species within the genus, which is not expressly disclosed, only if one of ordinary skill would immediately envision the claimed species from the disclosed genus.

The present application states that gold must be present in the amount of at least 76 wt%. In the present case, the chosen narrow sub-range of 76-83.5 wt% is based upon the fact that below 76 wt%, gold introduces undesirable eutectic phase that degrades color and lacks sufficient hardness. See the specification on page 6, "Control 2", wherein it is said that the specimen with 75 wt% Au resulted in large amounts of Au-rich eutectic precipitation which seriously degrades the surface color causing it to be reddish rather than purple. In addition, specimens of 80.5% Au, 81% Au, 79.7% Au, 79.7% Au, 79.4% Au, 77% Au demonstrated no signs of precipitate and the grain structure color was the desired pinkish purple.

In another aspect, the invention is described in the specification at page 4, where the gold content may be above 78.5 wt%, but only up to a maximum of 83.5 wt% to have the requisite toughness and by producing a gamma-phase gold aluminum structure.

The Office Action states that aside from anticipation, it would have been obvious to select a composition within the broad range to optimize the final violet color.

However, it can be seen that *Precious Metals* is devoid of any teaching as to the physical properties, such as hardness and toughness. In order to avoid brittleness and in order to achieve toughness and hardness, several criteria must be met, which are only taught in the present specification and as defined in Claim 1. Claim 1 states "alloy

... comprising 76-83.5 wt% gold and 16.5-21.5 wt% aluminium, and having a substantially purple hue.” The applied *Precious Metals* art is simply devoid of any teaching that would motivate one skilled in the art to select the gold composition, the aluminum composition and the ratio of over 3.66 in order to achieve color, hardness and toughness and avoid brittleness.

The Office Action with respect to Claims 2 and 3 admits that *Precious Metals* is silent as to hardness. The Office Action states that one skilled in the art would expect an AuAl alloy to have inherent hardness. This rejection is unfounded since there is no suggestion in *Precious Metals* as to the 3.66 ratio selected in the range to achieve such result. There is certainly no mention of the 78.5/21.5 selection.

The present specification demonstrates that compositions following within the range of *Precious Metals* lack hardness and toughness; are prone to surface indentations, surface fractures and brittleness in accordance with the controls of the Comparison Table submitted in the response filed January 29, 2003. An updated version of said Comparison Table is being submitted herewith as Attachment 1.

Claim 4 provides a further narrower selection within the broader range of Claim 1, and is submitted to be patentable and meet the criteria for novelty and non-obviousness for the reasons given with respect to Claim 1.

Claims 10 and 11, which depend from Claim 1, are directed to articles having the composition of Claim 1 and are submitted to be patentable for the reasons given with respect to Claim 1.

REJECTION UNDER 35 U.S.C. § 103

A. **Item 10 of Office Action:** Claims 1-4, 10 and 11 are also rejected under 35 U.S.C. § 103(a) as being unpatentable over Takiguchi (JP 59-093847).

The basis of this rejection is that Takiguchi teaches a purple-colored AuAl alloy that contains 15-30 wt% aluminum.

The Office Action also alleges that standards with respect to toughness desired has not adequately been specified in the present specification. Further, Examiner finds that the limitation as to at least 3.66 wt. ratio in the claims is not fully supported by data, which provides values only as low as 3.85. Responses to both of these requirements are provided herewith.

The Comparison Table originally earlier provided has been updated to show the HRB and results of Rockwell hardness testing already present in the specification as filed. Further data is also provided herewith as to the breakpoint 3.66̄.

The expanded Comparison Table under "Controls Comparison" shows that the controls under testing with a 200 g load gave a reading of victors 250, HRB range of 91-102.

In comparison, the 6 original examples of the present invention and the new example 7 being herewith showed HRB range of 96-104.5. (See new Example 7 data per attached **Declaration of Applicant** being submitted herewith (Attachment 2).

Under Rockwell Hardness B Test, Control Comparison #1 of the data and specification showed multiple fractures and Control Comparison #2 of the data and specification shows complete destruction with formation of precipitate.

In contrast, Examples of the Invention ##1-7 show all survived Rockwell Hardness B Test with no fractures and no precipitates.

In view of all of the above, there is abundant factual basis for determining what makes an alloy acceptable and what makes an alloy unacceptable, and abundant data on the record to support the claimed range of at least 3.66 wt. ratio of gold to aluminum, which is acceptable whereas a ratio of 3.65 is unacceptable. All ratios demonstrated in Examples 1-7 of the invention are above 3.66, that is, 3.66̄ and are acceptable. Clearly, there is an unexpected breakpoint taught only by the Applicant of the present invention.

Thus, Claim 1 is patentable over Takiguchi.

The Takiguchi rejection of Claims 2 and 3 on the basis of Takiguchi is essentially based on an expectation that one skilled in the art would arrive at all of the features of independent Claim 1 and dependent Claims 2 and 3, when such has been clearly demonstrated to not be the case.

Claim 4, which is dependent on Claim 1, has been rejected essentially on the same basis and is patentable for the reasons given with respect to Claims 1-3 above.

Claims 10 and 11, which depend from Claim 1, recite article and jewelry, and are patentable for the reasons given with respect to Claim 1.

In summary, Takiguchi teaches only a broad range of compositions for jewelry alloy containing 15-30 wt% aluminum. In contrast, the specification of the present invention teaches, in all circumstances relative to aluminum, that the ratio of Au:Al must be 3.66 or higher. See, e.g., the specification at Pages 3 and 5.

The specification beginning at Page 3 and throughout describes that the Au:Al ratio range of 3.66 or greater was selected because of its unexpectedly superior

metallurgical performance. This ratio produces an alloy with sufficient gamma-phase compound according to the Au-Al phase diagram referenced therein, while allowing the gamma compound to precipitate along the fine alloy grain boundaries when annealing according to the invention. The balance of the alloy composition is stated to be either Pd or Pd and Ni.

It is further stated in the specification that at this ratio range, the alloy produced is stable and anneals at temperatures of 600°C, and is of sufficient toughness and hardness that will withstand micro-hardness testing with 200 g load and subsequent Rockwell B hardness and not fracture. These features are not suggested in the prior art.

Accordingly, it is respectfully submitted that the record amply demonstrates the criticality of the 3.66 ratio as in independent Claim 1 and the claims which depend therefrom; i.e., Claims 2-4, 10 and 11.

B. Item 11 of Office Action: Claims 5, 6, 8, 9, and 13-15 are rejected under 35 U.S.C. § 103(a) as being unpatentable over *Precious Metals* in view of Miyama (JP 62-240729).

The basis of the rejection is that it would have been obvious to add nickel and or palladium as taught by Miyama to an alloy as defined in *Precious Metals*.

For the reasons described hereinabove, *Precious Metals* does not lead one skilled in the art to arrive at the specific combination of features as defined in Applicant's independent Claims 5 and 13 and Claims 6, 8, 9 14 and 15, which depend from respective Claims 5 and 13. Such claims are also patentable over *Precious Metals* for the reason that one skilled in the art would not be lead to arrive at any of the limitations

that: (1) gold content below 78.5 wt% is undesirable; (2) such gold content below 78.5 wt% having poor performance may be offset by judicious selection of alloy material; (3) gold content greater than 78.5 wt% and up to a maximum of 83.5 wt% is desirable, but above the upper limit is undesirable from a metallurgical point of view.

Further, only the present invention teaches that the art ranges encompass a very undesirable condition of pure intermetallic compounds stated at Page 3, Lines 20-25; namely, the intermetallic 78.5 wt% Au and 21.5 wt% Al and Au/Al ratio of 3.65; and to avoid gold content of 78.5 wt% or less, unless an additional element is present for the reasons stated.

Miyama does not supply the deficiencies of *Precious Metals*, since it does not supply the aforesaid features.

Therefore Applicant's invention as defined in independent Claims 5 and 13 herein capture critical and heretofore undefined and unknown narrow ranges, which alone lead to advantageous metallurgical properties as well as good color properties.

In addition, the Office Action makes the following statement regarding Miyama:

Regarding the fact that Miyama teaches a powder metallurgy alloy, one of ordinary skill in the art would have expected in Ni and/or Pd to have the same effect upon the alloy whether it was added into a cast article or a powder metallurgy article.

This assertion has no foundation in fact and is actually contrary to powder metallurgy and cast alloy principles.

The Examiner's attention is respectfully directed to Van Nostrand's Scientific Encyclopedia, Seventh Edition, Volumes I and II, excerpts of which that pertain to powder metallurgy and casting are attached hereto.

It is evident and fundamental that castings and powder metallurgy produce different materials. In fact, the section on powder metallurgy specifically states that the temperatures for powder metallurgy are below the fusion point of the principle constituents; therefore, bonding occurs, but alloying does not occur. Thus, powder metallurgy produces a very distinct product below the melting point of the constituents. In contrast, casting produces materials cast from starting constituents in fluid form into a cavity. There is relatively a homogeneous alloy obtained.

The very essence of powder metallurgy is to cause union between finely divided metal powders through use of pressure and heat for bonding, but not through the process of alloying as by melting.

Also attached is Fig. 9.30 from *Introduction to Ceramics, 2nd Ed.* (by Kingery et al. of MIT, pub. by John Wiley & Sons, Inc., 1976, page 421) illustrating a solid state reaction in a powder mixture. Here, a different reaction product layer forms on the bonding surface and the interior of the particle remains unchanged.

Thus, adding Ni or Pd to Au and Al particles cannot possibly have the same effect as when added to a cast article.

Therefore, there is no basis for the statement in the Office Action as noted above that melt casting and powder metallurgy produce the same result. Examiner is herewith requested to withdraw this rejection or provide support for same.

The translated passage of Miyama relied upon by Examiner is not accurately represented. Actually, a correct translation is given below, as prepared by Shigeumi Okumura, a native Japanese technical specialist employed by Harness, Dickey & Pierce:

The intermetallic compound that was processed though, changing the material color tone by adding Cu, Ni, Zn, Co, Pd, Ag, etc. to Au, using the intermetallic compound of Au-Al directly, or using a heat treatment after composing a film of Au and Al by PVD method, has been used as decorative gold alloy.

Thus, the Ni and Pd is just one of the unlimited selection of additives. Plus, such additives are one of the many methods said to affect color.

There is simply no suggestion to select Pd or Ni from among the countless possibilities.

Further, the Ni and Pd of the present invention are selected to affect physical properties. There is nothing in the prior art to suggest the use of Ni and Pd was to make the alloy hard (less brittle), as in the case of the claimed invention. While it is important that the alloy is hard, it must also be tough (malleable) enough so as to use it in intricate jewelry designs. Such intricate designs would not be possible if the alloy is brittle.

C. Item 12 of Office Action: Claims 5, 6, 8, 9, and 13-15 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Takiguchi in view of Miyama.

The basis of this rejection is founded on the unsupported interpretation of Miyama, the misapplication of powder metallurgy principles to casting and the attempted use of hindsight in view of the lack of teachings of both Miyama and Takiguchi as described herein immediately above in Section B.

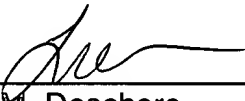
CONCLUSION

It is believed that all of the stated grounds of rejection have been properly traversed, accommodated, or rendered moot. Applicant therefore respectfully requests

that the Examiner reconsider and withdraw all presently outstanding rejections. It is believed that a full and complete response has been made to the outstanding Office Action, and as such, the present application is in condition for allowance. Thus, prompt and favorable consideration of this amendment is respectfully requested. If the Examiner believes that personal communication will expedite prosecution of this application, the Examiner is invited to telephone the undersigned at (248) 641-1600.

Respectfully submitted,

Dated: 12 MAY 04

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Attachments:

1. updated Comparison Table (originally submitted January 29, 2003);
2. Declaration of Applicant;
3. excerpts from Van Nostrand's Scientific Encyclopedia, 7th Ed., Vol. I and II; and
4. Fig. 9.30 from *Introduction to Ceramics*, 2nd Ed., an illustration of solid state reaction in powder mixture

COMPARISON TABLE

					Performance Values				
					Au / Al Ratio	Performance	Color	HRB	Values – Rockwell Hardness B Test
Controls Comparison					Au / Al				
1	78.5	21.5	3.65	Hard, brittle, surface fractures	Good, purple	102	Multiple fractures		
2	75	25	3.0	Too soft, surface indentations	Poor, Al surface deposits	91	Precipitation destroyed structure		
Examples of the Invention									
1	80.5	19.5	4.13	Tough, hard	Good, purple	101	Survived test – no fractures, no precipitates		
2	81	19	4.26	Same	Same	96	Same		
3	79.7	19.3 + Pd	4.13	Same	Same	103	Same		
4	79.7	19.3 + Ni	4.13	Same	Same	97.5	Same		
5	79.4	18.6 + Pd	4.27	Same	Same	97	Same		
6	77	20 + Pd	3.85	Same	Same	104.5	Same		
7	78.51	21.46	3.66	Same	Same	102	Same		

Independent Claims of the Invention

Claim 1 3.66 or greater Au/Al

Claims 5 & 13

76% -83.5% Au plus one of two additives max 4%

Art

JP '729 70-83% Au, 30-17% Al, 7-30% Ni, Co, Pd
JP '847 70-85% Au, 15-30% Al

Precious Metals

78.5-85% Au 15-21.5% Al

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in the gardens of Europe for its purple decor. An American counterpart, the *C. obovatus*, is a highly colorful plant and often used in gardens and landscaping.

Tung oil, a powerful drying oil, is obtained from the seeds of *Aleurites fordii* and closely related species, also in the family *Anacardiaceae*. This is a tree of China. The sap of *Rhus verniciflua* yields a furniture lacquer.

Some species of sumac find acceptance in gardens, notably the varieties shown on the accompanying table. Although the various sumacs, such as the staghorn and dwarf sumacs, are generally considered as shrubs, the dimensions shown in the table indicate the large proportions they can assume when situated in very favorable conditions.

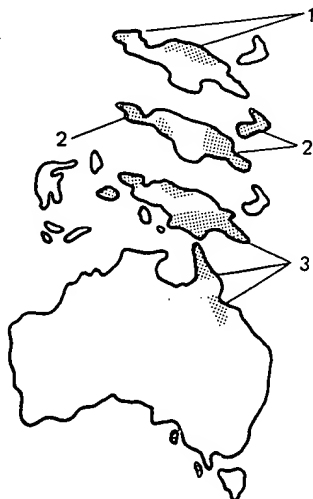
CASSIOPEIA (the chair). One of the most widely known and striking constellations of the northern latitudes. Cassiopeia is easily recognized by the five bright stars forming an irregular W, some observers seeing not only a W, but also a chair. Since this object is circumpolar for most northern countries (i.e., remains above the horizon at all hours every night, and is easily recognized, it is frequently used as a rough indicator of sidereal time. The leading bright star of W (the star Beta Cassiopeiae) lies almost in zero hours right ascension. Hence, a line drawn through Polaris and Beta Cassiopeiae must pass close to the vernal equinox. The hour angle of this line must be equal to sidereal time. Thus, when Beta Cassiopeiae is on the meridian directly above the pole, the sidereal time is zero; when it is on the meridian directly below the pole, the sidereal time is 12 hours, etc.

One of the brightest novae on record appeared in this constellation in 1572, and was observed and recorded by Tycho Brahe. (See map accompanying entry on **Constellations**.)

CASSITERITE. The mineral cassiterite, chemically tin dioxide, SnO_2 , is almost the sole ore of tin. It is a noticeably heavy mineral crystallizing in the tetragonal system, as low pyramids, prisms, often very slender, and as twinned forms. It is a brittle mineral, hardness, 6.0-7.0; specific gravity, 6.99; luster, adamantine; color; generally brown to black, but may be red, gray to white, or yellow; streak whitish, grayish, or brownish; may be almost transparent to opaque. A fibrous variety somewhat resembling wood is called wood tin. Cassiterite occurs in widely scattered areas, but deposits of a size to be commercially important are few. It is associated with granites and rhyolites.

Cassiterite is heavily concentrated in bands and layers of varying thickness, forming economically valuable deposits, such as those found in the Malay States of southeastern Asia; Bolivia, Nigeria, and the Congo are also major producers of tin ore. Cassiterite is also known as tin stone.

CASSOWARIES (*Aves, Casuariiformes, Casuariidae*). A family of birds closely related to the emus; they inhabit the primeval forests of North Australia and New Guinea as well as some of its islands. See accompanying illustration.



Areas inhabited by the Cassowaries: (1) one-wattled cassowary (*Casuarius unappendiculatus*); (2) Bennett's cassowary (*Casuarius bennetti*); (3) Australian cassowary (*Casuarius casuarius*).

There is only one genus (*Casuarius*). With a height at the back of up to 100 centimeters (39 inches) and a weight of 85 kilograms (187 pounds), it is the heaviest bird next to the ostrich. The legs are very strong. There are three toes, the claws of the inner toe being up to 10 centimeters (4 inches) long and straight. The feathers, like those of the emus (see also Emu), have an aftershaft of equal length; the flight feathers are reduced to mere rods of thick keratin. On the head they have a helmetlike, horny structure. The head and neck are bare of feathers; instead some have skin folds on the neck. The species are distinguished according to the shape of the helmet and the form of the skin folds of the neck. The bare skin differs in color in the various species and subspecies, and can be bright red, yellow, blue and/or white. Males and females are similarly colored. The chicks have a yellow-brown downy plumage with dark brown longitudinal stripes, but after a few months they become uniformly brown. The eggs average 135×90 millimeters (5.3×3.5 inches) and weigh 650 grams (23 ounces); the surface is slightly wrinkled, and the color is a shiny grass green, which later darkens somewhat.

There are 3 species: (a) Australian Cassowary (*Casuarius casuarius*); (b) One-Wattled Cassowary (*Casuarius unappendiculatus*); (c) Bennett's Cassowary (*Casuarius bennetti*).

See also **Ratites**.

CASTING. A process for producing specific shapes of materials by pouring the material, while in fluid form, into a shaped cavity (mold) where the material solidifies in the desired shape. The resulting shape is also called a *casting*. In terms of metals, the art of casting is one of the oldest methods for making metal parts and is still used extensively even though numerous other methods for producing shaped metal products, such as forging, rolling, and extruding, have been developed. In terms of plastic materials, casting is also widely practiced.

Metal Casting. The production of a casting involves the use of a pattern, usually of wood or metal, which is similar in shape to the desired finished piece and slightly larger in all dimensions to allow for shrinkage of the metal upon solidification. The pattern is bedded down in a special damp sand by an operation called molding. When the pattern is removed it leaves an impression of the shape of the desired casting. This impression is completely surrounded by sand and provided with openings called gates through which the molten metal enters. After pouring and cooling the mold is broken open and the casting removed. All adhering sand particles together with any extraneous projections such as those left by the gate system are removed after which the casting is machined to the required finish.

The term is also applied to the casting of pig iron in blast furnace practice and the casting of ingots in steel-mill practice.

Centrifugal casting is applicable to the production of pipe and tubing, wheels, gear blanks, and other castings having rotational symmetry. While the mold is rotated on a horizontal axis for pipe and tubing, and on a vertical axis for wheels and gear blanks, a measured amount of molten metal is added. The mold may be sand or water-cooled metal for more rapid solidification. Centrifugal castings have good structure and density.

Metal molds are also used for making die castings and permanent mold castings. In the latter process a permanent metal mold is filled by gravity in the usual manner, while in die casting considerable pressure is exerted on the molten metal, insuring rapid and complete filling of the mold. Die-casting machines are highly mechanized for rapid and nearly automatic operation. The product is characterized by high dimensional accuracy and clear reproduction of mold details including screw threads, holes, and intricate sections, all of which greatly reduces the machining required. The process is limited in its application by the high cost of making alloy steel dies or molds. The lower melting zinc alloys and aluminum alloys are most successfully die cast; however, certain brasses and bronzes can also be die cast. Tin- and lead-base alloys are easily die cast but have limited application.

The zinc-base die-casting alloys are the most widely used. A typical composition is 1.0% copper, 3.9% aluminum, 0.06% magnesium, balance zinc. This alloy has a strength of about 45,000 psi (3,061 atmospheres) with 3% elongation in 2 inches (5 centimeters). Typical applications are carburetors, fuel pumps, tools, typewriter frames, instrument cases, and hardware which is often finished by chromium plating.

The investment or "lost wax" process has lately been revived as a

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method of making precision castings of metals such as steel and zinc having too high a melting point for die casting. A wax pattern is made in a die-casting machine, sprayed with a highly refractory slurry, dried, and embedded in sand. The mold passes through a furnace where the wax is melted or burned out, and the mold baked. The casting is then poured into the cavity left by the melting out of the wax, resulting in castings which rival die castings for dimensional accuracy.

See also **Iron Metals, Alloys, and Steels; Zinc.**

Casting of Plastics. Several families of thermoplastic materials are capable of taking form by casting, although the process differs considerably from that used for metals just described. Some plastic casting processes depend upon melting and solidifying, as with metals; others depend upon solubility, as in the case of *solvent casting*.

Acrylic castings usually consist of poly(methyl methacrylate) or copolymers of this ester as the major components, with small amounts of other monomers to modify the material properties. Incorporating acrylates or higher methacrylates, for example, lowers the heat deflection temperature and hardness and improves thermoformability and solvent cementing capability, but with some loss to weathering resistance. Dimethacrylates or other crosslinking monomers increase the resistance to solvents and moisture. Castings are made by pouring the monomers or partially polymerized syrups into suitably designed molds and heating to complete the polymerization. A large reduction in volume, sometimes exceeding 20%, takes place during the cure. The reaction is also accompanied by liberation of substantial heat. At conversion, the polymerization may become autoaccelerated, and the rate of conversion may increase rapidly until about 85% conversion is achieved. Thereafter, the reaction slows down and post-curing may be required to complete the polymerization. On the other hand, with certain materials combinations, a violent runaway polymerization can occur.

The syrups made prior to casting (and final polymerization) can be stored safely at a controlled temperature until required. The preparation of syrups in advance shortens the time in the mold, decreases the tendency for leakage from the molds, and greatly minimizes the chance of dangerous runaways.

The majority of acrylic casting is in the manufacture of sheet. Cast sheet generally is made in a batch process within a mold or cell, but the process can be continuous through the use of stainless steel belts. Molds consist of two pieces of polished (or tempered) plate glass slightly larger in area than the desired finished sheet. The mold (or cell) is held together by spring clips that respond to the contraction of the acrylic material during the cure. The plates are separated by a flexible gasket of plasticized polyvinyl chloride tubing that controls the thickness of the product. Once filled, the mold is moved to an oven for cure. Thin sheet is cured in a forced-draft oven using a programmed temperature cycle, starting at about 45°C and ending at 90°C. The curing cycle requires several hours, the period increasing with the size of the sheet.

In continuous casting, a viscous syrup is cured between two highly polished moving stainless steel belts. Distance between the belts determines the thickness of the sheets. Although less versatile, the continuous process eliminates a number of problems in handling and breakage of large sheets of plate glass used for the batch process. Continuous processing produces sheets of more uniform thickness and essentially eliminates warping.

Nylon casting is a four-step process: (1) melting the monomer, (2) adding catalyst and activator, (3) mixing the melts, and (4) casting. Molds must be capable of containing a low-viscosity liquid at temperatures of 200°C and must allow for normal shrinkage. Two-piece molds are commonly used for simple shapes. More complex shapes require molds that can be disassembled to remove the cast shape. Stresses that develop during the casting can be controlled by very slowly cooling the casting over a period of 24 hours or longer.

Solvent casting is sometimes used, as in the case of polyvinyl chloride (PVC) film. In this process, resins, plasticizers and other ingredients are added to a solvent (tetrahydrofuran) in an inert, gas-blanketed mixing tank. Thorough mixing and degassing are critical for producing high-quality film. The mixture, below the boiling point, is pumped to a casting tank. The solution is filtered to a particle size not exceeding 5 micrometers. The solution is cast onto a stainless steel belt which then enters an oven where solvent is evaporated from the film. After cooling, the film is stripped from the belt and wound into rolls. The gage of the film is controlled by the die opening, the pumping pressure, and

the speed of the belt, all variables which can be carefully monitored and controlled. Films made by this process have good clarity, low strains, and freedom from pinholes.

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CAST IRON. Iron Metals, Alloys, and Steels.

CASTOR (α Geminorum). The fainter star of the twins. Since these two stars are always considered together in the ancient literatures, the history and astrological significance will be found discussed under Pol-lux, the brighter of the two.

Astronomically, Castor is a very remarkable star. It was discovered, in 1719, to be a visual binary, with the magnitudes of the components 2.8 and 2.0. The separation is about 6 inches, and the star is certainly a true binary, but the period, probably of the order of magnitude of 350 years, has not yet been accurately determined. Each of the two components of the binary system is also a spectroscopic binary. Castor has a faint companion, separated from it by about 72 inches, but having the same parallax and proper motion. This companion is also a spectroscopic binary, with a period of slightly less than 1 day.

Sir William Herschel observed the binary nature of Castor as early as 1803. Later observations indicated that actually there is a group of six stars in the system. Ranking twenty-fourth in apparent brightness among the stars, Castor has a true brightness value of 27 as compared with unity for the sun. Castor is a white, spectral type A star and is located in the constellation Gemini, a zodiacal constellation. Estimated distance from the earth is 45 light years. See also **Constellations**.

CASTOR OIL (*Ricinus communis*; *Euphorbiaceae*). Castor oil is obtained from a short-lived perennial tree which occurs wild in tropical Africa and perhaps in India. Cultivation of the tree is widespread not only in the tropics but also in temperate regions, where it is often grown as an ornamental plant. In the tropics it becomes a tree 36 feet tall, with large coarse leaves often of reddish color, and green flowers. An annual herbaceous variety is grown widely and produces a superior oil. The seeds, borne three in each of the smooth or prickly capsules, have a hard mottled shell. These seeds are ejected violently from the mature fruit.

The principal use of the plant is for the oil which is contained in the seeds. This oil is pressed out without heating the seeds. The particular properties make this a valuable oil for specialized uses, such as low temperature lubrication. It is an important constituent of hydraulic brake fluid and other fluids where the degree of compressibility is important. Castor oil also finds medical uses, as an ingredient of special soaps, and in the preparation of some textile dyes. Ricin, an alkaloid present in castor oil, also has been used in insecticides. Prior to the preparation of refined castor oil for medical purposes, ricin must be removed.

CASUARINA TREE Of the genus *Casuarina*, there are approximately 30 species of what some authorities regard as among the oldest and robust of trees. The casuarina apparently can thrive and grow under what normally would be considered grossly adverse conditions. Some examples of adverse environments are given by N. Vietmeyer (*American Forests*, 22-63, February 1986); these include the toxic alumina of New Caledonia, the bare, baking sands of Senegal, the deserts of central Australia, the tropical, often waterlogged clays of Thailand, brackish tidal estuaries, the slag heaps of a cement factory, and so on. Vietmeyer refers to the casuarina as a ruggedly designed survival "machine" developed in the hot, parched soil, and relentless sun and salt of the Australian deserts. Part of this survival stems from its ability to fix nitrogen. Billions of bacteria swarm over the roots, absorbing air trapped in the upper soil and converting its nitrogen into ammonia which, in turn, fertilizes the tree. Root nodules of the casuarina can swell to a diameter in some trees of more than four feet (1.2 meter) and, in so doing, accommodate great numbers of bacteria. Probably the only great enemy of the tree is frost.

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tant physiological changes occur in the laying of a laying period, a fowl will consume surplus icularly from the skin. Thus certain parts of the iter as the fat disappears. Other important physio- some alteration in blood flow and in characteris- lvic arches and feathers as well. These changes gress slowly throughout the laying period. large, moist vent. The vent is dilated and loose uckered vent of a nonlaying hen. The pelvic ure so as to increase the abdominal capacity of

Rapid Solidification Processing. As reported by Wright et al. (1987), RSP holds high promise for producing engineering alloys with refined microstructures, improved chemical homogeneity, extended solute solubility, and possible retention of metastable phases. RSP usually involves cooling rates greater than 100°C/second (212°F/s). For high cooling rates, RSP products must have a large surface-to-volume ratio, and thus are commonly in the form of powder, flakes, or ribbon. To be commercially acceptable, such rapidly solidified particulates must be consolidated into fully dense, metallurgically bonded forms suitable for engineering applications. RSP properties are quite sensitive to heat treatment and the desired properties can easily be lost without careful control over the consolidation process. Among the consolidation methods currently in commercial or near-commercial use include hot extrusion, hot

The reactions can be controlled in which some of the previous

isostatic pressing, vacuum or inert-atmosphere pressing or sintering, and powder forging. Unfortunately, these processes require elevated temperatures for relatively long times, which may destroy the benefits achieved by RSP. A major problem involves the tenacious oxide that forms on the surface of many RSP materials, particularly aluminum, nickel, and stainless steels.

A shock wave moving through the medium at velocities in excess of that of sound appears to be one solution to this problem. The shock wave can greatly exceed the yield stress. Passage of the shock wave causes plastic flow, interparticle melting and bonding, and can produce a fully dense, metallurgically bonded product. Three methodologies have evolved for introducing a shock wave: (1) use of a gas gun incorporating propellants or compressed gas; (2) direct application of explosives; and (3) impact of a projectile accelerated by explosives.

Guns are available of several designs. In one configuration, a high-pressure burst of gas launches a projectile down an evacuated tube where the projectile imparts a shock wave by driving a punch into the powder bed. As pointed out by Wright, the gun may be in the form of a high-impact press in which a reusable piston is accelerated in an evacuated chamber by introducing a rapid burst of gas into the breach. The impact of the ram produces a pressure pulse.

Hitchcox (1986) describes a process being developed at the Massachusetts Institute of Technology which uses high-velocity pulses of an inert gas to atomize a stream of molten metal. Semisolid droplets of the metal are collected as rapidly solidified "splats" on a chilled metallic substrate. (This liquid dynamic compaction (LDC) process is attractive from a cost standpoint.) Substrates can be flat surfaces, molds, or shaped containers. The splats build up rapidly, forming high-density bodies suitable for further processing. Because the splats are thin, they cool at relatively high rates (1000°C/second; 1800°F/s). It is claimed that the LDC process improves ductility and fracture toughness because oxides and powder particle boundaries are minimized. Although in an early stage of development, materials such as high-strength aluminum and superalloys and (FeCo)-Nd-B have been produced with the process. Grant (MIT) reports that rapidly solidified material may exhibit grain sizes as fine as 0.2 micrometer (8 microinches) after crystallization of glasses. The fine grain size allows superplastic forming of aluminum alloys, stainless steels, and other materials.

Self-Propagating High-Temperature Synthesis. Originally developed in the U.S.S.R., SHS usually involves an exothermic reaction producing temperatures in excess of 2500°C (4532°F). In essence, a mixture of compressed powders is ignited with a heat source in air or an inert atmosphere and in an instant, a refractory compound or multi-component material results. SHS eliminates the need for high-temperature furnaces as required by conventional processes. Processing time is shortened to seconds or minutes versus hours and days as required with normal sintering. The products, as reported by Sheppard, are usually of a higher purity, some having less than 0.2% (wt) of unreacted elements. This is the result of vaporizing volatile contaminants during the "explosion." SHS has been used to produce borides, carbides, and other difficult materials and is considered to have much potential for making ceramic matrix composites with unique microstructures.

In SHS, there are fundamentally two types of reactions: (1) *thermite*, where oxidation-reduction produces multiphase products, such as cermets; and (2) *compound formation*, as resulting from the starting elements, such as $Ti + 2B = TiB_2$. A combination of the two types of reaction also can be used. SHS requires a strong exothermic reaction where the heat of reaction is at least 40 kcal/mole (168,000 Joules/mole). The adiabatic temperature must be greater than the melting point of the product in order to produce a liquid phase for enhancing diffusion. Sheppard also breaks the reactions into (1) propagating, and (2) bulk. *Propagating reactions* are initiated locally, so that a synthesis wave passes through the material. The rate of heat dissipation must be less than the rate of heat generation, or the powder will be quenched. The heat dissipation is a function of particle size, bulk density, and surface/volume ratio. The powders must be sufficiently fine to enhance heat transfer into the unreacted material. In *bulk reactions*, the powder mixture is heated rapidly until the reaction occurs simultaneously throughout the entire sample. This type of reaction is sometimes referred to as a *thermal explosion*.

The reactions can be controlled, for example, by "kinetic braking," in which some of the previously reacted product is added to the mixture

of reactants, or, conversely, chemical activators can be added to accelerate the reaction. Also, if a higher reaction temperature is required, preheating of the reactants is practiced.

Examples of products made by the SHS process include borides, carbides, chalcogenides, hydrides, intermetallic compounds, nitrides, silicides, carbonitrides, sulfides, cemented carbides (cermets), and various heterogeneous mixtures (microcomposites).

PM Intermetallics and Additives. An example of improved materials for which PM technology may solve past metallurgical processing problems is found in turbine parts, where high-temperature performance and oxidation resistance are mandatory. Aluminides of iron, nickel, and titanium have received consideration for a number of years, not only because they appear to meet the two foregoing criteria, but also because of their relatively low density, high strength, and corrosion resistance. Conventional casting of these materials results in unacceptable inhomogeneities. This has led to the evaluation of several PM methodologies, including hot isostatic pressing (HIP), vacuum hot pressing (VHP), injection molding, transient liquid-phase sintering, reactive sintering, and hot extrusion. Of considerable promise, reflecting research at Rensselaer Polytechnic Institute, is *reactive sintering*. This process involves a transient liquid phase. The reaction takes place above the lowest eutectic temperature in the system, but still at a temperature at which the compound remains in the solid phase. Research has shown that a transient liquid forms at the lowest eutectic temperature and spreads through the compact during heating. Actually, the reaction is approximately spontaneous because heat is liberated due to the thermodynamic stability of the compound's high melting temperature. In terms of the reaction of nickel and aluminum powders, a temperature over 550°C (1020°F) is the optimum. The time required for processing is relatively short (about one-half hour). Densities over 97% (of theoretical) are obtained. Even with the presence of some residual porosity, the ductility and strength of the product are good, which properties are retained after subsequent high-temperature exposure.

Researchers at Case Western Reserve University and the NASA Lewis Research Center, both located in Cleveland, Ohio, have evaluated *hot extrusion* as a candidate process. In essence, the process consists of canning the powder (prealloyed aluminide powders [FeAl, NiAl, and Ni₃Al]) and then extruding the material at a temperature and area-reduction ratio sufficiently high to produce satisfactory material flow and efficient filling of interparticle spaces, the latter for eliminating porosity and to encourage grains to recrystallize dynamically.

A basic advantage of PM technology has been that of minimizing or eliminating machining in making a final part. Nevertheless, some machining operations may be required. Traditionally, the machinability of sintered PM steels, for example, is poor, mainly due to porosity, hardness, and low thermal conductivity. Porosity causes an interrupted cut and causes tool wear—with the possible results of both higher tool costs and poorer surface finish. In recent years, PM techniques have been improved by the incorporation of additives, notably manganese sulfide (MnS), to enhance machinability.

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